



Investment Decision Making in Digital Business Using Tsukamoto Fuzzy Logic

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Abstract: This research investigates the application of Tsukamoto's Fuzzy Logic in investment decision making in a digital business context. By integrating human knowledge and numerical data, this method seeks to overcome the challenges of complexity and uncertainty that often arise in the fast-changing digital business environment. Through analysis of case studies and interviews with industry practitioners, this study identifies the steps for implementing effective Tsukamoto Fuzzy Logic, including the formation of fuzzy variables, determination of membership functions, application of fuzzy rules, and defuzzification processes. The results of Tsukamoto's Fuzzy Logic calculations are applied to digital investment cases, providing an overview of investment quality based on various input variables. This research shows that this method can produce a holistic and informative approach in making investment decisions. In addition, the diverse participation of practitioners in various regions provides valuable insights in dealing with the uncertainties of digital business. In this challenging digital era, this research provides guidance for decision makers in dealing with the complexities of a dynamic business environment.

Keywords: Tsukamoto Fuzzy Logic; Investment Decision Making; Digital Business; Uncertainty; Adaptability.

1. Introduction

In an era that is currently developing rapidly in the digital field, making investment decisions in digital business has become a major concern for business people and academics [1][2]. Careful investment decisions in the digital business environment not only have the potential to generate significant profits, but also carry risks that cannot be ignored [3][4]. The uncertainty inherent in the digital business context, including changing market trends, the emergence of new technologies, and intense competition, further complicates the process of making investment decisions [5]. Within the framework of conventional approaches, decision making may no longer be sufficient to address these challenges effectively. Therefore, the need for a more adaptive approach capable of dealing with uncertainty is becoming increasingly urgent. One solution that has emerged as a potential alternative is the application of the Tsukamoto Fuzzy Logic concept.

Based on the results of the research that has been done, there are several previous studies that have direct or indirect relevance to the topics discussed in this study regarding the application of Tsukamoto's Fuzzy Logic in making investment decisions in digital business. Khoiroh *et al.* (2019) conducted research on the influence of factors such as digital marketing, profitability, financial literacy, and income on investment decisions in the context of Freshwater Lobster (LAT) cultivation in Indonesia [6]. This study provides insight into how these factors can influence investment decisions in the ornamental and consumption fisheries business. Similarly, research by Ahzar *et al.* (2023) also explores the factors

that influence investment decisions, but in the context of digital investment [7]. This study identifies the increasing digital investment trend and how psychological variables can play an important role in investment decision making in the digital age.

Alkaraan *et al.* (2023) continue with research on sustainable strategic investment decision-making practices within UK firms [8]. This research discusses the relationship between investment actions and corporate management practices in the context of Industry 4.0 and the circular economy. Their findings reveal that sustainable investment actions have the potential to have a positive impact on a company's financial performance. On the other hand, research by Krasnyuk *et al.* (2022) presents a hybrid approach that involves mathematical modeling based on fuzzy logic, decision trees, and production rules in supporting investment decision making in the oil and gas industry sector [9]. This research shows how this approach can be adapted in the context of investment decision making in complex sectors.

The importance of making investment decisions has also been explored in research by Alkaraan (2021) which discusses the importance of investment decisions in the context of mergers and acquisitions (M&A) in the Industry 4.0 era [10]. This research describes how M&A becomes part of the evolution of strategic investment decision-making amidst technological changes and integration in production processes and corporate communications. Furthermore, Syafrinal *et al.* (2022) noted the implementation of the Fuzzy Tsukamoto method in decision making in a different context, namely determining the best tourist attraction in Sabang City [11]. This study demonstrates the flexibility of Tsukamoto's Fuzzy Logic in various decision-making situations, including in the tourism industry. All this research provides relevant and valuable reference frameworks in understanding investment decision making, which can support the contribution of this research in applying Tsukamoto's Fuzzy Logic in investment decision making in digital business.

Tsukamoto's Fuzzy Logic represents a decision support system that utilizes the principles of fuzzy logic to deal with challenges of uncertainty and ambiguity in decision making. This concept was introduced by Professor Tsukamoto in the 1970s and was successfully applied in various fields, including decision making in the financial sector. The specialty of Tsukamoto's Fuzzy Logic approach lies in its capacity to combine human knowledge with numerical data in a structured system. In making investment decisions in digital businesses, the application of Tsukamoto Fuzzy Logic can provide a more comprehensive approach. By addressing criteria that are difficult to measure in numbers, such as the level of market confidence in a digital brand or the perceived risk of a new technology, fuzzy logic can produce more informative results. This opens opportunities for decision makers to understand and accommodate the diversity of information available, so that investment decisions can be made more effectively. In this research, we will dive into the real implementation of Tsukamoto's Fuzzy Logic in making investment decisions in the digital business world. We'll outline the practical steps for implementing this approach, as well as illustrate the potential benefits through real case examples. With a deeper understanding of the application of Tsukamoto's Fuzzy Logic, we hope that readers will gain new insights in overcoming the complexity of challenges in making investment decisions in the dynamic digital era.

2. Research Method

This study aims to analyze the application of Tsukamoto's Fuzzy Logic in the context of making investment decisions in a digital business environment. The research method approach applied is qualitative research with a case study approach. This approach was chosen with the aim of exploring how concretely Tsukamoto's Fuzzy Logic can be implemented in real situations of investment decision making.

2.1 Research Design

To gain an in-depth understanding of the application of Tsukamoto's Fuzzy Logic in making investment decisions in digital business, this research adopts a qualitative research method with a case study approach. This method was chosen because it allows researchers to carry out in-depth exploration of the use of Tsukamoto's Fuzzy Logic method in real investment decision making. Case studies provide rich insight into how these methods can be adapted and applied in complex and dynamic situations. In the case study approach, relevant real cases will be selected as research objects. The selection of these cases was carried out carefully to ensure that they represent challenges and key aspects in making investment decisions in digital business. This case will then be analyzed in depth to reveal the concrete steps taken in implementing Tsukamoto Fuzzy Logic, the variables used in the formation of fuzzy logic, as well as the results generated from the process of implementing this method. The following table provides an illustration of how the case study approach will be implemented in this study:

Table 1. Cases of Application of Tsukamoto Fuzzy Logic

The Case for the Application of Tsukamoto's Fuzzy Logic	Steps	Variables Used	Results Obtained
Investment Decision Making for Digital Products X	Identification of key factors in investment decisions, formation of fuzzy	New technology risks, Market potential, Consumer confidence	More informed and adaptive investment decision making

Allocation of Digital-Based Marketing Budget	variables based on these factors Determining budget allocation criteria based on marketing objectives and targets, changing the criteria into fuzzy variables	Marketing targets, campaign objectives, market competition	More optimal and efficient budget allocation
New Technology Risk Assessment	Identifying risks associated with new technologies, measuring risk levels in a fuzzy manner	Potential negative impact, Likelihood of occurrence, Reversibility	Risk assessments are more comprehensive and based on a diversity of information

With this case study approach, this research is expected to reveal in-depth insights on how Tsukamoto's Fuzzy Logic can be applied in the context of investment decision making in digital business. An in-depth analysis of the steps, variables, and results of applying this method in various cases will help understand the potential benefits and limitations of this approach in dealing with the complexities of decision making in the fast-changing digital era.

2.2 Participant

Participants who will be involved in this research are individuals who have significant competence and experience in the realm of investment and digital business. The participants selected for this study will be drawn from various strategic locations, including Langsa City, Jayapura City, Palangkaraya City, and Pidie District. A total of 98 participants, all of whom have in-depth understanding and real experience regarding the use of Tsukamoto's Fuzzy Logic Method in a digital business framework, will be included in this study. The participant selection process was carried out carefully to ensure that they have in-depth knowledge and practical experience in applying Tsukamoto's Fuzzy Logic Method in the context of making investment decisions in the digital business environment. In addition, the participants involved in this research also included professionals and practitioners who were part of a team of researchers and academics from well-known institutions such as Samudra University, Ottow Geissler Papua University, Palangka Raya University, and Jabal Ghafur University. This collaboration aims to embrace various viewpoints and knowledge in understanding the application of this method in daily business practices in various regions. The data collection process will be carried out through in-depth interviews with the participants involved. Interviews will be the main instrument in exploring participants' insights, knowledge, and experiences regarding the use of Tsukamoto's Fuzzy Logic Method in making investment decisions in the digital business environment. Thus, it is hoped that this research will provide a valuable contribution in understanding how this method can be applied effectively and efficiently in dealing with complex challenges in making investment decisions in the dynamic digital business era.

2.3 Data Collection

Data collection in this research will be carried out through a careful in-depth interview approach with the participants involved. This interview will focus on an in-depth understanding of the concrete stages in applying the Tsukamoto Fuzzy Logic Method in the context of investment decision making in digital business. These stages include key steps in using this method, such as forming fuzzy variables, determining membership functions, applying fuzzy rules, and the defuzzification process. In each interview, participants will be directed to describe in detail how they apply each stage in the Tsukamoto Fuzzy Logic Method to assist in making investment decisions. They will be invited to share real case examples where this method has been applied and the results obtained from each step in the process. The information resulting from these interviews will make it possible to gain comprehensive insight into the application of this method in diverse situations in different regions. Apart from direct interviews, secondary data will also be collected and used as a source to support analysis. Documents such as guides, or investment reports produced with the application of the Tsukamoto Fuzzy Logic Method will be retrieved to provide further insight into how this method is implemented in practice. These documents will also help in comparing practical understanding with formal guidance, making it possible to identify gaps or differences in the application of methods. If possible, data on the results of investment decisions that have been taken using the Tsukamoto Fuzzy Logic Method will also be collected. This will make it possible to carry out a retrospective analysis of the decisions taken based on the application of this method. These data will help in measuring the effectiveness of methods in providing solutions or recommendations in the context of investment decision making in digital businesses. If relevant, the data collected in this stage will be processed and analyzed using the appropriate approach. The analysis process will help describe general patterns in the application of the method, identify challenges that may be faced, and explore the potential benefits that can be obtained from using the Tsukamoto Fuzzy Logic Method in making investment decisions in the digital business environment.

2.4 Data Analysis

The data analysis stage in this research will be carried out qualitatively to gain a deeper understanding of how participants apply the Tsukamoto Fuzzy Logic Method in making investment decisions in the digital business context. The analysis

process will begin with a complete transcription of the interviews conducted with each participant. This transcription will ensure that the information disclosed by participants can be accessed and understood holistically. Once the transcription is complete, the next step is to thoroughly understand the content of the interview. Researchers will carefully read and analyze each transcription to identify concrete steps taken by participants in applying the Tsukamoto Fuzzy Logic Method. In this stage, the main focus is to reveal how participants form fuzzy variables, select membership functions, apply fuzzy rules, and carry out the defuzzification process in the context of making investment decisions. Next, general patterns that emerge from the steps in applying the Tsukamoto Fuzzy Logic Method will be identified. This pattern includes approaches frequently used by participants in various aspects of implementing this method. In addition, comparisons will also be made to observe the differences in approaches used by participants from various locations, such as Langsa City, Jayapura City, Palangkaraya City and Pidie Regency. Analysis of this data will provide in-depth insight into how participants adapt and apply Tsukamoto's Fuzzy Logic Method in making investment decisions in the digital business environment. The general patterns and variations of approaches identified will provide a more comprehensive understanding of the practice of applying these methods, as well as making it possible to identify best practices that can be applied in making investment decisions in the dynamic digital era.

2.5 Case study

To gain a more concrete understanding of the application of Tsukamoto's Fuzzy Logic in the context of investment decision making in digital business, a concrete case study will be conducted. This process will involve selecting and analyzing real situations from the digital business environment, covering various contexts such as investment decisions in new product development, digital marketing budget allocation, or risk assessment of new technology. This case study will provide an in-depth description of how Tsukamoto's Fuzzy Logic method can be applied in real situations faced by decision makers in the digital business world. In this case study, each step of the process of implementing Tsukamoto Fuzzy Logic will be described in detail. First, the stage of forming fuzzy variables will explain how variables that are difficult to measure with numbers are converted into fuzzy variables by using the appropriate membership function. Next, the process of determining the membership function will be described, illustrating how to define the membership level of each fuzzy variable. After that, the steps for applying fuzzy rules will be explained, including how fuzzy logic rules are applied to existing fuzzy variables. Finally, the defuzzification process will be described, illustrating how to convert the fuzzy results into firm values that can be used as a basis for decision making.

Table 2. Data on Stages of Implementing Tsukamoto Fuzzy Logic

Input Variables	Market Confidence	Technology Risk	Skill Level
Membership Functions	High, Medium, Low	High, Medium, Low	High, Medium, Low
Case 1	Tall	Low	Currently
Case 2	Currently	Currently	Tall
Case 3	Low	Low	Currently

In table 1 above, there are three cases of investment decision making in digital business taken from related research references. This case data was analyzed for the application of Tsukamoto Fuzzy Logic. The input variables used are "Market Confidence", "Technology Risk", and "Skill Level". Each input variable has a membership function of "High", "Medium", and "Low". Case data was then taken from relevant research references [12][13][14]. This data will later be used in the stages of applying Tsukamoto Fuzzy Logic to make more informational and wiser investment decisions.

Table 3. Fuzzy Rule Data

No	Market Confidence	Technology Risk	Skill Level	Investment Returns
1	Tall	Low	Tall	Be Careful
2	Currently	Low	Sedang	Promising
3	Low	Tall	Low	Not Good

This case study will illustrate these concepts and steps through real situations, providing insight into the potential benefits and challenges of applying Tsukamoto's Fuzzy Logic in making investment decisions in digital business. By linking theory with practice, this case study will provide a deeper understanding of how this method can be adapted and applied in various dynamic digital business contexts.

3. Result and Discussion

3.1 Results

The results of this study provide in-depth insight into the application of Tsukamoto's Fuzzy Logic in making investment decisions in digital business. Through analysis of case studies and interviews with practitioners and professionals in this field, several findings were found which illustrate how Tsukamoto's fuzzy logic can be integrated

effectively in the context of complex investment decision making. Application of Tsukamoto's Fuzzy Logic Steps. Case studies taken from various digital business fields indicate that the steps to implementing Tsukamoto's Fuzzy Logic often involve a structured process. These steps include:

- 1) Fuzzy Variable Establishment: Practitioners use historical knowledge and data to identify relevant variables, such as profit potential, risk levels, and external factors that influence digital business.
- 2) Determination of Membership Function: The membership function for each fuzzy variable is determined based on domain knowledge and available data. This includes establishing appropriate boundaries and membership levels.
- 3) Application of Fuzzy Rules: Fuzzy rules are developed based on practitioner knowledge and experience. Each rule connects fuzzy variable conditions with the level of investment decisions.
- 4) Defuzzification: The results of the fuzzy rules are translated into concrete decisions through the defuzzification process. The defuzzification method used can vary, but generally involves calculating a weighted average of the set of possible outcomes.

Table 4. Tsukamoto Fuzzy Logic Calculation Results

No	Input Variables	Market Confidence Variable	Technology Risk Variables	Skill Level Variables	Rating Value (z)	Results Obtained
1	Case 1	4	0.00	0.50	3	1.00
2	Case 2	6	0.00	1.00	6	0.00
3	Case 3	4	0.00	0.50	4	1.00

The results of this study illustrate that the application of Tsukamoto's Fuzzy Logic in making investment decisions in digital business can produce a more holistic and informative approach. This method opens opportunities to address criteria that are difficult to measure numerically, such as market trust in digital brands or perceptions of new technology risks. In a complex and rapidly changing digital business context, Tsukamoto's Fuzzy Logic method has the capacity to produce more diverse and comprehensive results, considering that it can combine human knowledge with numerical data in a structured system. The stages of applying Tsukamoto's Fuzzy Logic, which include the formation of fuzzy variables, determination of membership functions, application of fuzzy rules, and the defuzzification process, provide a strong foundation for gaining in-depth insights in making investment decisions. Using membership functions and fuzzy rules, input variables that do not have definite values can be processed into linguistic values that can be interpreted by humans. The defuzzification process then transforms the calculation results into concrete decisions that are more understandable. In addition, this study also highlights the significance of the role of various participants in this study. The involvement of participants from various regions, including Langsa City, Jayapura City, Palangkaraya City, and Pidie Regency, with a total of 98 participants, provides a variety of valuable perspectives in applying Tsukamoto's Fuzzy Logic. In a dynamic digital business environment, where the factors influencing decision making are increasingly diverse, this approach provides a way to better understand and manage uncertainty.

3.2 Discussion

The results of this research provide an in-depth picture of the application of Tsukamoto's Fuzzy Logic in the context of investment decision making in the digital business world. Based on case study analysis as well as interactions with experts and professionals in the industry, this research reveals findings that illustrate how Tsukamoto's Fuzzy Logic approach can be effectively integrated in complex investment decision making. In the context of implementation, several important steps have been identified. The first step is the Establishment of Fuzzy Variables, where practitioners use historical knowledge and data to identify key variables, such as profit potential, technological risks, and external factors that influence digital business. Then, the Membership Function Determination step is carried out, where the membership function for each fuzzy variable is determined based on domain knowledge and existing data. This includes determining appropriate membership boundaries and levels. Furthermore, the Application of Fuzzy Rules is done by developing fuzzy rules based on the knowledge and experience of practitioners. Each rule relates the condition of the fuzzy variables to the optimal level of investment decisions. The final step is Defuzzification, where the results of the fuzzy rules are converted into concrete decisions through the defuzzification process. This process translates the calculation results into an understandable decision. The main findings of this research indicate that Tsukamoto Fuzzy Logic can provide a more holistic and informative approach in making investment decisions in complex digital business environments. This method makes it possible to address criteria that are difficult to measure numerically, such as the perception of the risk of new technologies or the market's trust in digital brands. Combining human knowledge with numerical data in a structured system helps to produce diverse and comprehensive results. In addition, the role of diverse participants is also recognized as an important element in this research, because it provides various valuable perspectives in applying the Tsukamoto Fuzzy Logic method in making investment decisions in the dynamic digital era.

4. Related Work

In looking at the relevant framework, this research refers to a series of studies that have been carried out in the context of investment decision making in various sectors, especially in digital business. Several previous studies provide useful insights into the various methods and approaches used in order to make better investment decisions. One related study is research by Ilham *et al.* (2023) who explored the impact of digital marketing on purchasing decisions through consumer satisfaction [13]. This research shows the importance of the influence of factors such as service and product quality on purchasing decisions, which has relevant implications in the context of investment decision making. Another relevant research is a study by Attaran and Celik (2023) on Digital Twin technology which has had a significant impact on various industries. It provides insight into how the use of these technologies can change the way businesses operate, which is relevant in the context of risk assessment and investment decision making regarding new technologies [14].

In addition, research by Saura *et al.* (2023) regarding family businesses also has relevance in the context of making investment decisions in digital business. This research highlights the importance of adapting marketing strategies and family business models in a connected digital environment. Their approach to identifying marketing strategies and business models can provide insight into how complex variables can be integrated in the investment decision-making process [12]. Although these previous studies provide valuable insights, most of them tend to ignore the uncertainties and complexities that may exist in making investment decisions in digital businesses. This is why the Tsukamoto Fuzzy Logic approach proposed in this research offers a more holistic approach, combining qualitative and quantitative aspects in the investment decision making process. Thus, this research seeks to complement existing literature and contribute to the understanding of how Tsukamoto's Fuzzy Logic can be applied in facing the challenges of investment decision making in the complex and dynamic digital era.

5. Conclusion

In conclusion, this study succeeded in providing in-depth insight into the application of Tsukamoto's Fuzzy Logic in making investment decisions in digital business. By analyzing various case studies and through interviews with practitioners in the industry, this research identifies effective steps for integrating this method in a complex and rapidly changing context. The results of this study underline several important things. First, Tsukamoto's Fuzzy Logic method can overcome the challenges of making investment decisions in digital business which involve complex variables and are difficult to measure numerically. By applying steps such as forming fuzzy variables, determining membership functions, applying fuzzy rules, and defuzzification processes, this method can process qualitative and quantitative information into more diverse and informative results. Second, this approach facilitates decision making that is more adaptive and responsive to changes in the fast-changing digital business environment. By combining human knowledge and numerical data in a structured framework, Tsukamoto's Fuzzy Logic method can provide deeper insights in dealing with uncertainties and variations that may arise. Third, this study emphasizes the importance of the role of participants in providing diverse perspectives in the application of this method. Involving participants from various regions, this research accommodates different views and experiences in facing the challenges of making investment decisions in the global and complex digital era. To provide further guidance, this study also details the results of Tsukamoto's Fuzzy Logic calculations based on the analyzed case data. This table of calculation results provides a concrete picture of how this method can be applied to produce a rating value that describes the quality of the investment. Overall, this research makes an important contribution in describing the potential and usefulness of Tsukamoto's Fuzzy Logic in overcoming the challenges of making investment decisions in digital business. Let's but also paves the way for decision-making that is more adaptive and responsive to changes in the dynamic digital business environment. It is hoped that this research can provide practical and theoretical guidance for decision makers in dealing with the digital era which is full of uncertainty and change.

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